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WADD TECHNICAL REPORT 60-388

A NEW CHRONIC POLAROGRAPHIC IMPLANT UNIT FOR MEASUREMENT OF CEREBRAL OXYGEN AVAILABILITY

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Biomedical Laboratory
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MAY 1960

WRIGHT AIR DEVELOPMENT DIVISION

NOTICES

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Project No. 7165
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WRIGHT AIR DEVELOPMENT DIVISION
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

This work was performed under Project No. 7165, "Health Hazards of Materials and Radiation," Task No. 71836, "Evaluation and Control of Toxic Chemical Materials," during the period of December 1958 to August 1959. The work was initiated by the Toxic Hazards Section, Physiology Branch, Biomedical Laboratory, Aerospace Medical Division, of the Wright Air Development Division.

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Animal experimentation was performed in accordance with the Rules for Animal Care as established by the American Medical Association.

ABSTRACT

This report describes the design and development of a chronic brain polarographic implant unit capable of detecting small changes in cerebral oxygen availability (aO_2). The design and fabrication of this unit: (a) provide for integral construction of both an anode and a cathode in a single assembly (the brain probe, cathode, may be changed or replaced without removal of the basic polarographic unit) and (b) improve surgical implant methods resulting in a simple, rapid, and relatively bloodless operation. Reproducible data can be obtained within 5 days (often as soon as 2 days) following postsurgical recovery.

PUBLICATION REVIEW

Andres I. Karstens

ANDRES I. KARSTENS, Colonel, USAF, MC
Chief, Biomedical Laboratory
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A NEW CHRONIC POLAROGRAPHIC IMPLANT UNIT FOR MEASUREMENT OF CEREBRAL OXYGEN AVAILABILITY

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INTRODUCTION

The direct measurement of the concentration of dissolved oxygen in various organ and tissue fluids by polarographic techniques has been extensively reported (refs. 1 to 5). Methods for recording oxygen changes in the brain have been described for acute (refs. 1, 5) and chronic (refs. 3, 4) preparations. For chronic brain studies, many investigators have employed acrylic polymer resins as support and sealing material for polarographic electrodes implanted into the skulls of experimental animals. Surgery was often time-consuming because the exposed skull area had to be clean and dry when plastic resins were used and the resinous mass had to be molded in place during the operation. Also, the completed units lacked electrical stability. This was probably due to the failure of the resinous material to provide adequate insulation.

Our purpose was to design and fabricate a new brain polarographic implant unit to eliminate or reduce many of the undesirable electrical and surgical shortcomings of previous designs. A simple prefabricated assembly with integrated anode and cathode was developed. This report discusses the design, construction, surgical and recording procedures, and performance specifications of this unit.

THEORY AND DESIGN

The small depolarizing current produced as a result of two half-cell reactions involving an electron donor and an electron acceptor may be measured through a

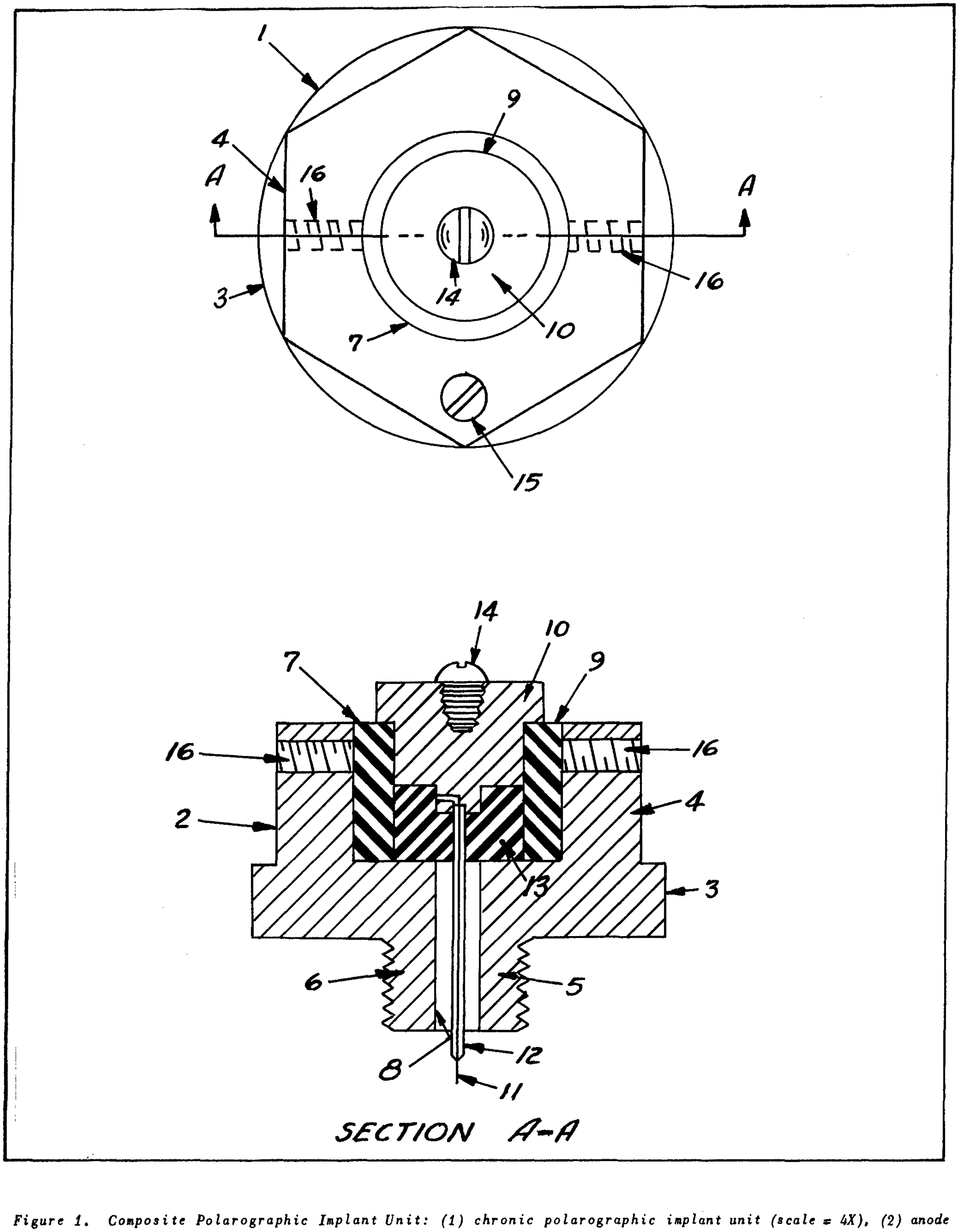

Figure 1. Composite Polarographic Implant Unit: (1) chronic polarographic implant unit (scale = 4X), (2) anode body, (3) circular base, (4) hexagonal portion, (5) short extension, (6) threads, (7) well to accommodate cathode and insulation assembly, (8) well extension, (9) nylon insulation ring, (10) cathode plug, (11) platinum wire, (12) glass capillary insulation, (13) paraffin, (14) cathode terminal screw, (15) anode terminal screw, (16) Allen set screws

suitable recording circuit. In this instance the silver-plated anode body acts as the electron acceptor. The magnitude of this current is proportional to the oxygen availability (aO_2). Davies and Brink (ref. 1) offer a more detailed discussion of the theory.

Scale drawings (4X) of the composite polarographic implant unit with the cathode and insulation assembly in place are shown in figure 1. The anode consists of a silver or silver-plated body with a circular base. Above the circular base is a hexagonal portion and below is a short extension threaded throughout its length. Both of these features allow the unit to be screwed easily into the skull of the experimental animal.

The cathode and insulation assembly consists of a metal cathode plug, an insulating ring, and a glass-fused platinum probe. The nylon ring insulates the anode body from the metal cathode plug. A length of 28-gauge platinum wire is centrally secured and soldered to the cathode plug. The wire is surrounded by an insulating glass capillary tube except for a 2-mm. portion at the end. The remainder of the cathode assembly is filled with paraffin to insulate further the cathode from the anode body. The cathode and anode are both provided with terminal screws for connection to the recording circuit. The cathode probe, cathode plug, and insulation components are constructed as a single unit. It is locked into place in the anode body by two Allen set screws. This design permits the cathode assembly to be removed for repositioning or replacement by another cathode unit.

ELECTRICAL CIRCUITRY

A block diagram of the polarograph and recording system is shown in figure 2. The polarographic unit, previously described by Clark et al. (ref. 3), consisted of an Ayrton-type shunt circuit for applying a polarizing voltage of 0 to 1.5 volts. The depolarizing current was passed through an oscilloscope, * utilizing its vertical amplification system, to a recording galvanometer, ** having a full-scale deflection of one milliampere. In addition, a second oscilloscope was added to the system to allow polaroid photographs to be taken simultaneously. A 3,200-ohm resistance was inserted in series between the amplifier and recording galvanometer to minimize drift in the oscilloscope amplifier system and to equalize the sensitivities of the paper recorder and the oscilloscope (see figure 2).

SURGICAL PROCEDURES

This implantation unit permits surgical operations requiring no sutures to be performed. An insignificant amount of hemorrhage results. The animals are anesthetized with pentobarbital sodium administered intravenously. Sterile surgical procedures must be maintained to prevent the occurrence of postoperative infections, especially since the unit may be kept in place for long periods of time. The head of the animal is clipped and prepared for aseptic surgery. The frontal bone is palpated and the location

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* Type 532 cathode-ray oscilloscope with type 53/54D preamplifier plug-in unit, Tektronix, Inc., Portland, Oregon

** Model AW, recording galvanometer, Esterline-Angus, Inc., Indianapolis, Indiana

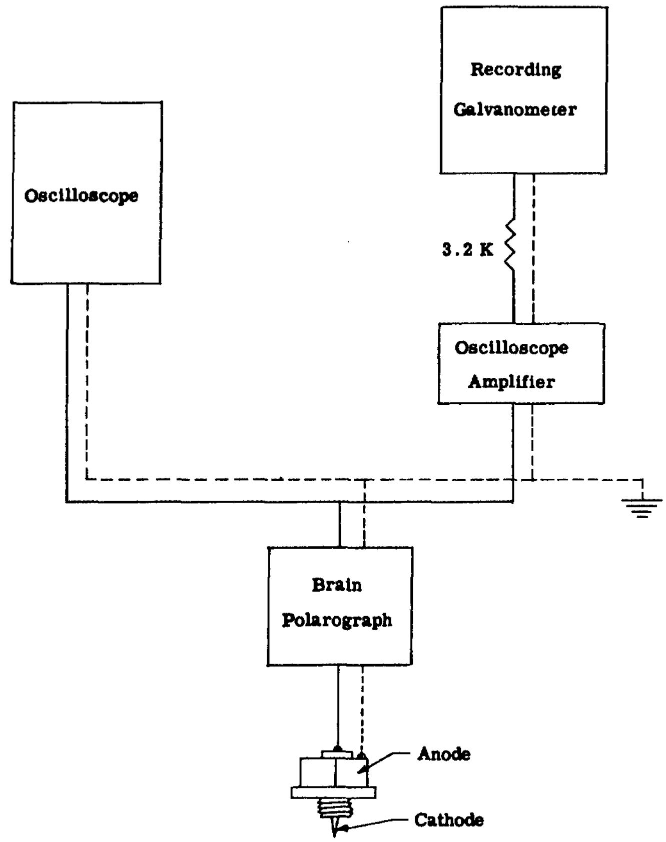

Figure 2. Brain Polarograph and Recording System

of the trephine opening is imprinted on the skin. This position is determined on a 2-kilogram cat by locating the nuclear crest and proceeding 3 centimeters anterior on the midline and 1 centimeter lateral from this point. Care is taken to locate the point laterally enough to prevent insertion of the cathode into the fissure separating the cerebral hemispheres. A circular incision approximately 1-1/2 centimeters in diameter is made and the underlying tissue removed. Unlike previous electrode devices requiring dry skull surfaces to permit adhesion of acrylic resins, it is unnecessary to completely remove tissue or to provide a dry area. A pilot hole is then drilled through the frontal bone with a small dental burr. A large, hollow-center bone trephine is then employed to enlarge the opening sufficiently to accommodate the threaded stem portion of the anode body (figure 3). The bone trephine is constructed so that the bone particles will be forced into its hollow center instead of falling into the skull cavity where they might serve as focal points for irritation or subsequent, foreign-body reactions. Extreme care must be exercised to prevent injury to the dura mater and the surface of the cerebrum during both trephining operations. Frequently bone wax is employed to control hemorrhage from the blood sinuses of the frontal bone. The anode body is then inserted using a heavy, downward, clockwise motion so as to thread it into the frontal bone. Threading is continued until the anode base is securely tightened against the skull. In an ideal situation, the bottom of the stem portion is flush with the ventral surface of the frontal bone. This is not absolutely critical provided the stem portion does not produce direct pressure on the surface of the brain, thereby producing subsequent pressure necrosis. At this point, the cathode and insulation assembly is then inserted into the anode base,

the set screws are tightened, and the operation is complete. X-ray photographs should then be taken to ascertain whether there is any damage to the tip of the platinum probe and to determine the position of the probe and unit in relation to the skull and cerebral tissues. These polarographic units, when implanted by this procedure, have remained in place up to 70 days prior to removal at necropsy without restricting a cat's normal activity.

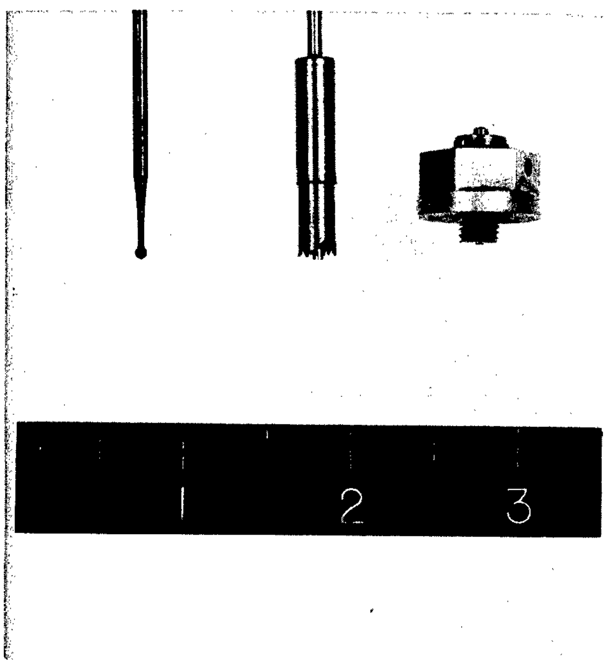

Figure 3. Implant Unit and Drills for Surgical Procedures

RESULTS

The effects of oxygen and nitrogen administration* are shown in figure 4. The straight-line horizontal trace below the normal, oxygen, and nitrogen recordings represents the reference level (base line) where no signal was allowed to reach the oscilloscope.

Maximum effects of the oxygen or nitrogen occurred approximately 20 seconds after administration, with 20 to 30 seconds generally required for recovery to ambient conditions. The nitrogen trace approached the base line very closely. As this occurred the cat showed clinical symptoms of marked hypoxia.

Rhythmic variations were regularly observed as having a frequency of approximately 6 to 10 cycles per minute (figure 5). On the lower trace, these periodic fluctuations are shown as normally recorded, whereas the upper trace depicts the fluctuations at a tenfold increase in sensitivity. These periodic fluctuations are in agreement with the results reported by other (refs. 3, 4).

The effects of lowering the partial pressure of oxygen by using an altitude pressure chamber are seen in figure 6. Oxygen partial pressure values in the range of 160 to 50 mm. Hg represent simulated altitudes of 0 to 30,000 feet. A linear pO_2-polarograph relationship is evident.

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* The experimental animal breathed pure oxygen or nitrogen until a maximum or minimum was reached on the recording trace.

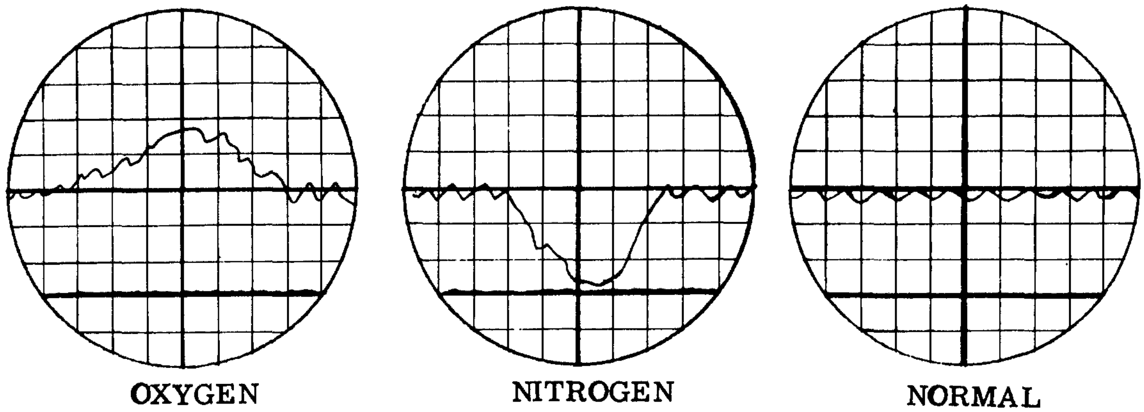

Figure 4. Effects of Oxygen and Nitrogen Administration on Cerebral aO_2 in Cats. Read from right to left. Scale divisions in cm. Horizontal sweep speed is0.1 cm./sec. Vertical deflection is 10 mv./cm. (Figures are handdrawn copies of Polaroid photographs taken with a Dumont oscilloscope camera.)

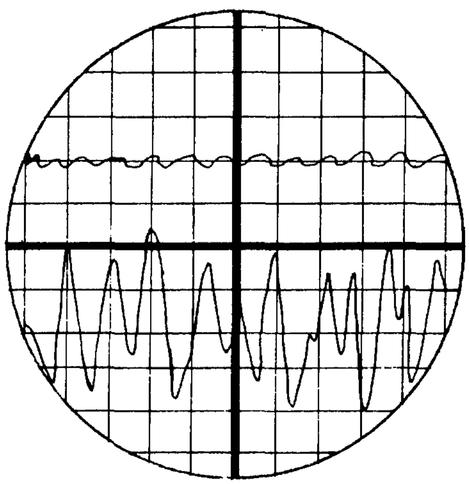

Figure 5. Rhythmic Variations in aO_2. Read from right to left. Scale divisions in cm. Horizontal sweep speed is 0.1 cm./sec. Vertical deflection-lower trace: 10 mv./cm., upper trace : 1 mv./cm. (Figure is handdrawn copy of Polaroid photograph taken with a Dumont oscilloscope camera.)

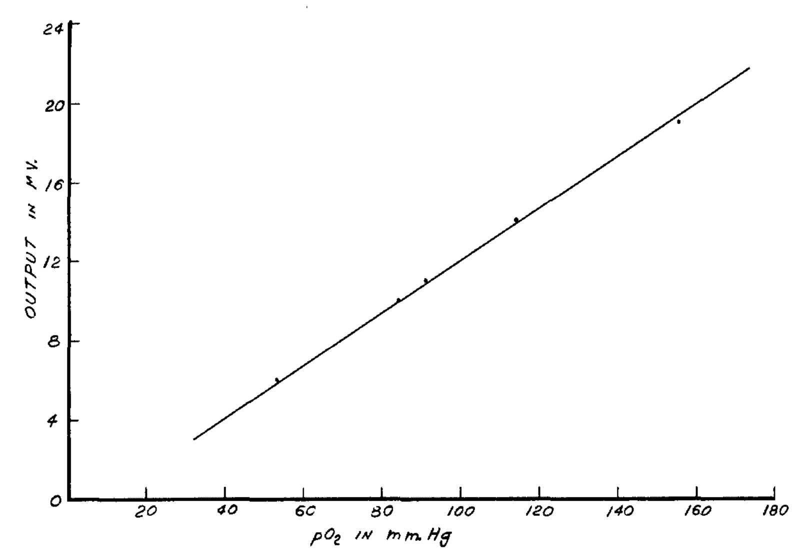

Figure 6. Graph Showing the Effects of Lowering the Partial Pressure of Oxygen (pO_2)

SUMMARY

An improved chronic brain polarographic implant unit for detecting small changes in cerebral oxygen availability has been developed. The design provides for integral construction of the anode and cathode.

Implantation requires a total operative time of 20 minutes. The incision is small and no bone scraping or drying is required. The entire unit is prefabricated and easily screwed into the skull. The base of the unit serves as the anode and consequently the older system of implanting metallic bars subcutaneously and intramuscularly is obviated. Thus, problems of inflammation, infection, and sloughing of tissue are kept to a minimum. The apparent discomfort to the subject is minimal and there are no sutures to cause irritation. The subject is not able to scratch the area of surgical intervention in the scalp since the flange portion of the unit completely covers this area. This unit has another advantage in that the cathode probe can be removed and repositioned to a more sensitive region of the brain.

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